INTERNATIONAL ENERGY AGENCY

Implementing Agreement for Co-operation in the Research, Development and Deployment of Wind Turbine Systems
Task 11

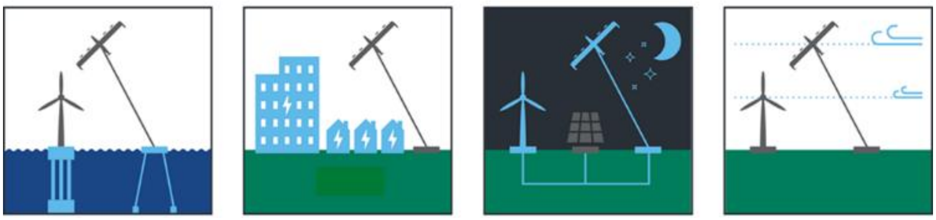
Topical Expert Meeting #102 on

Airborne Wind Energy: Challenges and Opportunities

IEA Wind Task 11

September 23 & 24, 2020

Online meeting



Technical Lead and Host:
Kristian Petrick, Udo Zillmann, Stefanie Thoms – AWEurope
Chris Vermillion – NCSU
Jochem Weber - NREL
Roland Schmehl – TU Delft
Andy Clifton - WindForS

Operating Agents:
Nicolas El Hayek – Planair SA
Lucas Mosca – Planair SA

Disclaimer:

Please note that these proceedings may only be redistributed to persons in countries participating in the IEA Wind TCP Task 11.

Participating countries are contributing financially and in-kind for this work and are therefore expecting that the results of their efforts stay within this group of countries.

The list of countries to which the documentation can be distributed is available in Appendix Five.

After one year the proceedings can be distributed to all countries, that is September 2021.

Copies of this document can be obtained from:

PLANAIR SA
Rue Galilée 6, 1400 Yverdon-les-Bains, Switzerland
Phone: +41 (0)24 566 52 00
E-mail: ieawindtask11@planair.ch

For more information about the IEA Wind TCP please visit www.ieawind.org.

Table of Contents

Executive Summary of TEM#102

Introduction

Airborne wind energy (AWE) has the potential to give access to stronger and more stable high-altitude wind resources, including in remote areas and floating offshore, and thus could have an important part to play in the future energy mix. It also reduces material consumption which leads – in combination with a higher capacity factor – to potentially very low LCOEs and lower carbon and environmental impacts. Furthermore, it may be modified to provide propulsion and power for the maritime shipping sector.

There are currently over 60 organizations working on AWE, thereof about half from industry developing AWE systems and half from academia and government research (see Figure 1 of the Introductory Note, Annex One). AWE is progressing towards commercial demonstration. A recent road mapping exercise among Airborne Wind Europe members concluded that AWE system deployment can be expected to be in the Gigawatt-range by 2030. By 2050 several hundreds of Gigawatts will be potentially installed providing a significant share of the power supply.

However, various questions need to be answered before AWE achieves widespread commercial adoption. The objective of the IEA Wind Topical Expert Meeting number 102 (TEM#102) was to inform on the challenges concerning safety standards and technical guidelines, resource and deployment potentials, markets, engineering issues, environmental impacts and social acceptance, regulatory as well as financial and policy challenges. The participants are to reach an agreement on the research priorities and propose a role for the IEA Wind TCP to coordinate an international collaboration effort.

Meeting Overview

TEM#102 on Airborne Wind Energy was organized by Airborne Wind Europe, Kyushu University, NC State University, NREL, TU Delft and WindForS on September 23-24 as an online meeting. A total of 92 participants and few observers from 18 different countries with expertise in airborne wind energy joined the discussion during the two days. In addition to a great response across the industry and research institutes, the organizers were pleased to welcome members of governmental bodies and fellow IEA Wind Task operating agents to TEM#102.

The first day began with an introduction session where the organizers presented the IEA Wind TCP framework, the mission statement of the TEM and the background and vision for AWE. The rest of the meeting was composed of four sessions following the same format: two selected experts presented their experience on a given topic of AWE and answered questions from the audience. After their talks, participants divided into small groups to discuss and prioritize research topics, identifying any roadblocks, relevant research project and meaningful work packages for international collaboration in the frame of an IEA Wind Task. All participants then gathered again, and each group’s note taker briefly summarized the main takeaways that were discussed. A total of eight topics were discussed in over 30 break-out groups.

A short “online speed-dating” at the start of each day allowed each participant to introduce himself to two fellow experts, and to gain thus an overview of their field of expertise.

Main Results

The IEA TEM#102 has been a successful event to exchange knowledge, views and insights on Airborne Wind Energy among a wide range of participants.

The organizing team concluded that the idea to establish a new IEA Wind Task on Airborne Wind Energy has been confirmed by the TEM. Four key topics for collaborative research in future Working Groups were identified in line with the strategic objectives of the IEA and the research priorities of IEA Wind:

- Resources, potential and markets

  Beside wind resource measurement conditions and evaluations against flight campaigns, topics of interest include potential markets, on- and offgrid, on- and offshore, LCOE and cost curve development, as well as modelling of future energy scenarios which include AWE; this would also facilitate the development of a roadmap for the AWE sector.

- Social Acceptance

  Social and environmental impacts of AWE, including noise, birds and bats, are relevant. Non-technical expertise like social sciences may also be involved in order to investigate how neighbors and society perceive AWE.

- Safety and regulation

  Aspects related to airspace regulation, closely working with competent regulatory authorities, are of special interest. Concept of operations, risk assessment, U-Space integration, standardization, zones, etc. must be discussed.

- Reference models, tools and metrics

  The development of joint reference model(s), simulations, tools, common definition of metrics and performance indicators as well as functional requirements are needed in order for the sector to move forward.

The topics of education (e.g. common master programmes) and electrical systems are second priorities and could be the object of a work package at a later stage.

The next steps will be that the team will seek support from the IEA ExCo when presenting the Task Proposal and then prepare the future Task to be started early 2021.

Summary of Presentations

The information in this section provides an overview and selected highlights of each of the presentations during TEM#102. Discussion results are summarized in the next chapter.

All meeting material from TEM#102 is available on the IEA Wind website, on the TEM#102 community page. Access for download can be requested from the Task 11 Operating Agent.

Day 1: September 23, 2020

Introduction session

John McCann, Chair of the IEA Wind TCP, welcomed the approach on an IEA Task on Airborne Wind Energy or even a new TCP on Airborne Wind Energy. He highlighted the great potential of AWE in onshore, offshore and off-grid applications.

Nicolas El Hayek from Planair SA (Task 11 Operating Agent) welcomed all participants and provided a short overview of the IEA Wind TCP and of Task 11, presenting the organization's goals and the Task's activities such as Topical Expert Meetings and Recommended Practices. In particular, the participants were made aware of IEA Wind's mission and of how they can benefit from an international collaboration effort. A more detailed presentation about the IEA Wind TCP is available online in the meeting documents.

A "speed-dating" session was introduced which allowed the participants to chat in randomly created break-out groups of three people for three minutes, thus giving the opportunity to have some personal exchange similar to an in-person conference.

Udo Zillmann from Airborne Wind Europe provided the current state the AWE sector within a short presentation for newcomers, explaining the concept, different systems, advantages, milestones achieved and potential markets of AWE.

Roland Schmehl from TU Delft presented the visions for the AWE sector. These are (1) to make AWE the cheapest form of energy based on its resource availability and material savings, (2) to make AWE the most acceptable form of energy based on its low environmental footprint, and (3) to combine AWE with other renewable energy technologies to accelerate the transition to a 100% renewable energy system. However, commercially developing AWE is technologically ambitious, costly and also risky. There are still many obstacles to surpass and development times are generally much longer than expected. Especially the pronounced multidisciplinary character of the pursued technologies requires a very systematic approach. To tackle these challenges, secure financing of R&D, as a combination of public and private sources, is needed, as well as societal and political support and a motivated, passionate and well-educated workforce of researchers and engineers. Two strategies are followed, a short-term commercialization (1-3 years to market entry) for small-scale AWE systems (up to several 100 kW) that exploit the high mobility, low weight and rapid deployment features and a longer-term commercialization (5-15 years to market entry) for larger-scale AWE systems (MW range) that target massive deployment scenarios and exploit the full potential of AWE.

Jochem Weber from NREL closed the introduction session with a presentation on "TEM mission statement" and shared high-level characteristics of the mission the IEA task may target. These task characteristics were subsequently disseminated to the delegates to be considered as criteria for consideration and selection of task topics.

Session 1 – Resource potential & Environmental and social integration

Philipp Bechtle from Uni Bonn gave an overview of the Resource Potential: Wind Studies and Power Curve of AWE. A key advantage of AWE systems is that they can access wind at altitudes that are beyond the reach of conventional tower-based wind turbines and that the harvesting altitude can be adjusted continuously to the available wind resource. Because the operational envelope of AWE systems, especially those operated in pumping cycles, is more complex, the definition of power curves requires more care.

Kristian Petrick from Airborne Wind Europe dove into the topic of environmental and social integration of AWE. The environmental footprint and social impacts of AWE (e.g. bird collisions, noise, visual impacts) are largely unknown because there are only a few systems operational. The same holds true when it comes to benefits when comparing with other forms of energy generation, for instance reduced life-cycle-emissions, possibility to restore original site conditions, flexibility in operations.

Session 2 – Safety aspects and regulation & Common design tools, reference models

Michiel Kruijff from Ampyx Power discussed Safety aspects and airspace regulation. In contrast to towered wind turbines, AWE systems include one or more flying components and as consequence reliability and safety are of crucial importance. While AWE systems based on soft wings and rigid wings have different safety characteristics, yet they all require new standards and regulation.

Chris Vermillion from NC State University presented a range of design tools, reference models, and accessible experimental data. Several academic institutions have developed accurate, experimentally validated tools for the design, aerodynamic analysis, and simulation of AWE systems. He highlighted the need for the dissemination and training on open-source AWES modelling tools (many of which exist but are not sufficiently widely known). These tools are also important for third party assessment of AWE.

Day 2: September 24, 2020

Recap from day 1

Kristian Petrick from Airborne Wind Europe gave a short overview of the agenda of the day before another speed-dating session was held.

Session 3 – Functional requirements & Electrical system

Jochem Weber from NREL opened session 3 with Functional Requirements, Metrics & Technology Assessment. Given the diverse nature of technology concepts and engineering solutions in the nascent airborne wind energy sector, the criticality of market specific and solution agnostic functional requirements and relevant evaluation metrics were discussed, as these may support comparative and absolute technology assessment and most importantly guide decision to achieve cost, time and risk effective technology development trajectories towards market entry.

Christoph Hackl from the Munich University of Applied Sciences presented approaches on the Electrical system of AWES. AWE technology poses a number of challenges to the electrical system, e.g. due to the extreme operation characteristics of pumping-mode AWE systems with their slow reeling-out and (very) fast reeling-in which leads to an extremely wide speed range of the electrical drive system. Oscillating power generation, voltage and frequency stability will become more important.

Session 4 – Educational needs & Road mapping

Roland Schmehl from TU Delft presented his vision on educational needs. AWE is a relatively new and widely unknown field. Experienced people are scarce not only within the sector but also among important stakeholders like policy makers, utilities, administration, project developers, energy companies, etc.

Daniel Zywietz from Enerwhere shared his insights on AWE from a customer perspective, especially referring to off-grid applications for temporary mining and resource extraction where functional requirements (and value propositions) are quite different to on-grid systems.

Jon Gjerde from Kitemill then gave an overview of the challenges to create a sector road map for the short and long term, to define realistic scenarios, set challenging yet realistic targets and to agree on joint milestones.

Final session

Nicolas El Hayek from Planair SA (Task 11 Operating Agent) highlighted the next steps after TEM#102, leading to a new IEA Wind Task proposal. He encouraged all meeting participants to engage into this process and to contact the organisers to express their interest in an international collaboration effort on selected AWE R&D topics.

Udo Zillmann from Airborne Wind Europe closed the meeting and thanked all participants, speakers, breakout session chairs and notetakers for their active participation. He also thanked the meeting organisers for their great work in making this online meeting a success.

Breakout Session Notes

The breakout discussions that took place in each session saw the participants split into small groups after the research area presentations to discuss in parallel the state-of-the-art, identify research gaps and needs for future collaboration for each area:

- Wind resource potential & power curves; Environmental and social integration
- Safety aspects and airspace & planning regulation; Common design tools, simulations and reference model
- Functional requirements, metrics and technology assessment; Electrical system
- Educational needs; Road mapping

The outcomes of each discussion group were presented in plenum in the form of three takeaways during a short synthesis. The following section provides a consolidated summary of the thoughts and notes from each of the breakout sessions based on the notes of each group.

1. Wind resource potential and power curves

It was discussed that it is fundamental to demonstrate the potential of AWE for the development of the technology and for financing (e.g. EU funding). Resource studies that link to economic performance need to take the adaptability and harvesting characteristics of different AWE types into account. Realistic simulation models are important, and they need to be checked against real flight data as well as experimental measurements of high-altitude wind.

Another important topic is how to define a power curve for AWE systems, ideally using a common, standardised methodology and tools. Participants mentioned various challenges: gusts and turbulences, strong variations for different altitudes, 10 mins averaging for AWE not appropriate, flicker issues, establishing a reference altitude and shear profiles, different air densities, wake and drag effects, flight path optimization, etc. Other environmental conditions like storm swells are also necessary to be considered in offshore installations.

2. Environmental and social integration

Social acceptance was generally seen as crucial for the deployment of AWE systems. The involvement of the local population in connection with a comprehensive site selection process, which also covers aspects like impact on nature and wildlife, noise emissions, value-add for local communities were discussed. Moreover, the sustainable design of AWE was pointed out as one important dimension. Reliable studies on these topics need to be conducted and compiled and experiences from existing research and initiatives (like Task 28) drawn. A potential working group on “Social acceptance for AWE” could include all these issues.

3. Safety aspects and airspace & planning regulation

Risk assessment and concept of operations (which are coupled, along with safety and operational zones) were considered as very important. The idea of having joint regulation development in close cooperation with national and supra-national aviation authorities (like EASA and FAA) as well as AWE integration in the U-Space concept have also been mentioned multiple times. It also needs further discussion if AWE (or certain AWE concepts) will have to be treated rather as drones or obstacles. It may be possible to further develop Makani’s standardization gap analysis (with IEC 61400) and FAA rulemaking for AWE as obstacle (near to final stage). It may be too early for AWE standardization; instead, sharing guidelines and aligning on existing regulations could lead to easier certification process. Standardization can happen only after market penetration.

4. Common design tools, simulations and reference model

The array of available design tools within the AWE community was shown to be vast and sometimes overlapping. There was wide recognition, through the session itself, breakout discussions that followed, and the survey at the end of the workshop, that the development of a working group aimed at model standardization and training would be of great benefit to the community. A similar sentiment was shown to exist for reference models. Several discussions were initiated in regard to the usefulness of available experimental flight data in validating modeling tools, including the limitations of that experimental data, and the usefulness of incentives for organizations to share this data and liberally instrument their AWE systems to provide rich data sets for ongoing research efforts. These topics merit further discussion, as potentially facilitated by the new IEA task.

5. Functional requirements, metrics and technology assessment

Further development of tools for assessment and definition of metrics was requested across the breakout groups. Functional requirements were agreed to be of high importance, are clearly market specific, are required to be expressed in a solution agnostic way and need to be holistic, covering all cost and performance drivers as well as a wide range of acceptability aspect over the lifecycle of the technology and across all stakeholders. Especially, the comparative assessment across technologies and the sequential assessment guiding the technology development process were regarded as highly important. The presented concept of Technology Performance Levels (TPL) was regarded as interesting and beneficial to cluster a multitude of performance metrics and was recommended to be developed for AWE systems. The two-dimensional representation and consideration for technology development trajectories over Technology Readiness Levels (TRL) and TPL was regarded as valuable and that it would be insightful to review the Makani development process in this framework.

6. Electrical system

In all three break-out groups related to this topic the need to distinguish Flygen and GroundGen systems was stated. Flexible grid integration and optimal operation of the electrical system were discussed with different points of view, that led to the requirement of a certified, intelligent storage (if and where really needed) and connection solutions / integration (also DC-link interconnection), in order to prove a seamless uptake and parallelization/synchronisation of several AWE systems to e.g. smooth power generation.

Finally, the need of a holistic electrical system design (in particular electrical machine design) which considers the AWE-specifics (like load changes due to the pumping cycles) was pointed out.

7. Educational needs

AWE is a relatively new and widely unknown field. Experienced people are scarce not only within the sector but also among important stakeholders like policymakers, utilities, administration, project developers, energy companies, etc. During the TEM it was noted that:

- More experts with specialized education to a Masters or PhD-level are required. Although there may not be many jobs at this time, it takes years to train up a workforce and it is therefore necessary to start this process early. An AWE-specific course would be helpful, but only at Masters level or beyond. Even if the sector does not take off, the students would still obtain a useful STEM degree.

- An IEA Task could enable an international Masters course, for example between DTU, Delft, and other universities in Europe, or in the USA or Asia.
- There is a pressing need for a text book, which could also be coordinated by a Task.
- Education at Masters level and above benefits from close cooperation with end users. This can include defining projects, sharing ideas for research, or employing students for training periods. The Task could serve as a meeting point for educators and end users and help enable this collaboration.

It was noted that some of this coordination could be taken up by other organisations, e.g. the European Academy of Wind Energy (EAWE), but that a Task could support and enable this information exchange.

8. Road mapping

Policy and regulatory support for AWE was seen as a crucial prerequisite to successfully cross the “valley-of-death” towards commercialization. To convince policy makers and equity funders and also for public awareness, the sector needs to establish **targets and reach certain milestones** (e.g. several hundred thousand flight hours, showing reliability, decreasing cost curves). Achieving them is again not easy without financial support; they are also market-, scale- and technology-specific. Regional funding should be ideally combined with national funding. However, despite the importance, policy and regulation is not the typical subject of a Task and probably difficult to justify; work on this topic may be continued by AWEurope for the time being.

Markets were seen as another key element: Niche markets like off-grid avoids having to compete with conventional wind or other technologies but they have other challenges (e.g. far away from current OEM locations). Entering the European on-grid market will not be possible without specific support for AWE. In the long run, the offshore market is the most challenging but maybe one of the most promising for AWE.

It was acknowledged that **road mapping** is not easy; reaching short-term goals was seen as important but setting long-term goals as well. Such an exercise should be done with a larger community of stakeholders including customers, suppliers and academia. There was agreement that the AWE potential is large and that it should be taken seriously by policy makers and energy scenario modelers.

As conclusion it can be noted that a **WG could combine the topic of a roadmaps, milestones, targets, etc. with studying resource potential** because there are similar aspects to be looked at, e.g. when it comes to modelling cost curves but also future markets (wind resource, technical potential, economics, etc. Modeling groups (from IEA, IRENA or national institutes) must have the info they need to include AWE as separate, own RE technology.

Conclusions & Next Steps

Given the large attendance and the fruitful discussions that took place during TEM#102, the organizing committee concludes that the two-day online meeting was a success. A large number of participants agreed on the need and expressed interest in the formation of a new IEA Wind Task tackling unique aspects linked to Airborne Wind Energy and involving parties from other TCPs.

Based on the notes from the individual sessions, a poll before and after the TEM, as well as further deliberations among the organizing committee, the proposed topics for a task are the following:

- **Resource potential and markets**

  Question to be answered: Where to deploy AWE?

  This WP would include not only the wind resource measurement conditions and evaluations against flight campaigns but also potential markets, on- and offgrid, on- and offshore, LCOE and cost curve development, as well as modelling of future energy scenarios which include AWE; this would also facilitate the development of a roadmap for the AWE sector. The WP may also include a joint technology assessment approach.

  Potential deliverables: Conditions for AWE-relevant wind measurements and maps, entry-markets, costs curves, AWE scenarios.

- **WG on Social Acceptance**

  Question to be answered: What are AWE benefits for society and environment?

  The WP would include both social and environmental impacts of AWE, including noise, birds and bats, etc. This WG may also involve non-technical expertise like social sciences in order to investigate how neighbors and society perceive AWE.

  Potential deliverables: guidelines for site selection; surveys and studies.

- **WG on Safety and regulation**

  Question to be answered: How to deploy AWE safely?

  This WP would include especially aspects related to airspace regulation, closely working with competent regulatory authorities. It discusses concept of operations, risk assessment, U-Space integration, standardization, zones, etc.

  Potential deliverables: Guidelines and standards

- **WG on Reference models, tools and metrics**

  Question to be answered: How to deploy AWE efficiently and how to measure it?

  This WP would includes development of joint reference model(s), simulations, tools, common definition of metrics and performance indicators as well as functional requirements

  Potential deliverables: reference model(s), design tools, common definitions of metrics and KPIs.

Topics that may be taken up at a later stage include:

- Education: Common master programmes
- Electrical systems

The next steps include:

- Communicate with key stakeholders over the course of next few months
- Continue to update and refine the task proposal
- Further develop detailed work packages (WP)
- Solidify participant countries, organizations and individuals
    - Letters from participants including commitment, leads on WP’s and ExCo contact
- Assign leads responsible for each WP
- Refine budget estimates for participating countries

The aim is to submit a final proposal by December 2020 or early 2021 and to start the new Task within Q1-2021.

APPENDIX ONE – TEM#102 Introductory Note

INTRODUCTORY NOTE

IEA WIND TASK 11 TOPICAL EXPERT MEETING #102

ON

AIRBORNE WIND ENERGY

Kristian Petrick, Udo Zillmann – Airborne Wind Europe
Andy Clifton – WindForS, Germany
Chris Vermillion – NC State University, USA
Jochem Weber – NREL, USA
Shigeo Yoshida – Kyushu University, Japan

BACKGROUND

Airborne wind energy (AWE) has the potential to give access to stronger and more stable high-altitude wind resources, including in remote areas and floating offshore, and thus play an important part in the future energy mix. It also reduces material consumption which leads – in combination with a higher capacity factor – to potentially very low LCOEs and lower carbon and environmental impacts. Furthermore, it may be modified to provide propulsion and power for the maritime shipping sector[1].

There are currently over 60 organisations working on AWE, thereof about half from industry developing AWE systems and half from academia and government research (see Figure 1 in the annex).

AWE is progressing towards commercial demonstration. A recent road mapping exercise among Airborne Wind Europe members concluded that AWE system deployment can be expected to be in the Gigawatt-range by 2030. By 2050 several hundreds of Gigawatts will be potentially installed providing a significant share of the power supply.

However, there are various questions that need to be answered before it achieves widespread commercial adoption. The challenges concern safety standards and technical guidelines, resource and deployment potentials, markets, engineering issues, environmental impacts and social acceptance, regulatory as well as financial and policy challenges.

The TEM has been initially proposed by the University of Stuttgart (Germany), and is supported among others by

- IFP Energies Nouvelles (France),
- Kyushu University (Japan),

[1] For further reading and references, see e.g. http://www.kitepower.eu/publications.html, https://awec2019.com/book-of-abstracts-series or www.airbornewindeurope.org/

- NC State University (US),
- NREL (US),
- PtJ / BMWi (Germany),
- SEAI (Ireland),
- TU Delft (Netherlands),
- Wind Energy Research Cluster (Germany),
- and the leading AWE companies which are members of Airborne Wind Europe.

The TEM is intended as a virtual online meeting on 23-24 September. It is the clear intention to establish a specific Task on AWE within the IEA Wind TCP.

ADDED VALUE OF COLLABORATION

An IEA Task on AWE will allow tackling various of the specific challenges on a global level by addressing and including stakeholders who are not primarily AWE developers, i.e. policy makers, authorities, regulators and experts.

So far, the AWE community has been consisting mainly of developers and research institutions which convene every two years at the AWE Conferences (the last one took place in October 2019 in Glasgow). The sector association AWEurope has started about two years ago with collaborative activities among its members (working groups on safety, sector roadmap and recently on environmental and social impacts) but – even though being also open to non-European members – its main focus has been on Europe. Recently the sector has also been present at the WindEnergy Hamburg fair and conference and, within the European Academy of Wind Energy network (eawe), a technical Committee on AWE has been set up in 2019 which convenes about twice a year.

An IEA Task on AWE would be highly beneficial in order to open the scope of collaboration to the whole world; it will thus foster a truly international exchange of expertise, produce and gather new data and information, allow for joint learning, as well as accelerate the development of AWE technology and thus its impact on the international energy sector. AWE stakeholders will be able benefit from the experience and established networks within IEA Wind while also providing new insights and technological expertise to them.

OBJECTIVES

The focus of the TEM is to prepare the activities of a future Task on AWE and the creation of a global AWE community to which R&D groups and other stakeholders, including members from other tasks (e.g. Task 25 System integration, Task 26 Cost of Wind, Task 28 Social, Acceptance, Task 41 Distributed Wind, etc), can contribute to with the aim to achieve a breakthrough of this technology. The idea is to discuss the research topics below plus any other ideas brought up by participants, prioritize them and then – once the AWE Task has been established – start working on them in dedicated Working Groups within the Task (similar to the way Task 32 is organized).

Suggested topics include:

Feasibility and technology assessment:

- State of AWE technology: Where do we stand? What are the key challenges and barriers? What is the recent progress?

- Compiling Frequently Asked Questions: How to find answers on (technical) FAQs on AWE? E.g.: Is automated take-off and landing for all technologies solved? What is the longevity of components like tethers, drums, connection pieces, kites, etc. under environmental conditions (sea water, sunlight, snow, ice, lightning, …)?
- Safety: Which safety aspects should be standardized in design, operation and maintenance?
- Design tools: Which sector-wide design tools could be developed together to allow benchmarking and reference standards, addressing engineering and other challenges and leveraging the community's strengths and diversity, e.g. on dynamic behaviours and power curves, or developing an open-source kite simulator (like NREL's FAST turbine simulator)?

Assessment of potentials:

- Scenarios for 2030 to 2050: Which will be AWE sector's contribution to global Energy supply and CO2 reduction (also by using less material)? What is the space availability onshore and offshore considering potential restrictions (e.g. distances to settlements, wind resource availability, other uses like air traffic)? Which will be its role in each of the continents (Americas, Asia, Europe, Africa, Oceania)?
- Viability and efficiency: How will the power curves look like? What can be the energy yield per km2 considering e.g. distances between kites and wake effects? How long will kites really be able to fly, and which capacity factors can they realistically achieve? What is the overall efficiency of the entire cycle and extended periods of time including maintenance intervals? What is the LCOE potential?

Policy and Regulation:

- Policies for AWE: Will AWE require policy support? If yes, what would be appropriate, effective and efficient schemes? What can be learned from other RE technologies?
- Airspace Regulation: How to harmonize regulatory approaches for AWE in order to avoid that countries start developing own procedures?
- Environmental and social impacts: How to best determine the impact on fauna, measure noise and investigate visual impacts? How to measure and increase social acceptance?

SPECIFIC OUTCOMES

The outcomes of the meeting include:

- Minutes of the meeting capturing the key discussion points
- Task proposal including preliminary list of proposed activities for submission to IEA Executive Committee
- Presentations from the participants
- One pager with key results of the meeting that can be published on the websites of IEA Wind and other participating organisations (see next section).

INTENDED PARTICIPATION

The targeted audience includes organisations from all around the world that are specialized in AWE, have worked on AWE or have shown interest, see also Figure 1 in the Annex below. The following is an initial list which – in the likely case of a virtual event (see below) – will be extended to all the organisations and countries shown in Figure 1 as well as others:

- AWE developers and suppliers: Ampyx Power (NL), Enerkite (DE), Kitemill (NO), Kitepower (NL), KiteSwarms (UK), Skypull (IT), Skysails Power (DE), Twingtec (CH), Windlift (US)
- Wind energy developers and manufacturers: GE, Siemens Gamesa, Vestas.
- Wind park owners and operators, utilities: PG&E California, RWE, Engie, Vattenfall, Shell, Equinor
- Universities / research institutions: NREL, Kyushu University, NC State University, TU Delft, Politecnico Milano, University of Freiburg, University of Stuttgart, ETH Zürich, Technical University of Munich, Fraunhofer IWES, Leibniz University of Hannover, JRC, DLR
- Policy makers: Ministries for R&D, energy, economy and/or environment in all IEA Wind countries, European Commission
- Public authorities: FAA US, EASA, JARUS, Swiss FOCA, other National Aviation Authorities

TENTATIVE PROGRAM

The TEM is being planned for 23-24 September 2020. The initial idea was to hold the meeting back-to-back with Wind Energy Hamburg conference and fair, but as this event has been postponed to December 2020 an online meeting is proposed (4 hours each day).

The objective of the first day is to enable everyone having a view on the topics and decide together which ones will be discussed in details during the second day of the meeting in break-out sessions. The objective is a proposal for a new IEA Wind Task on Airborne Wind Energy.

Prior to the meeting

A survey conducted in two rounds will seek to gather initial data on invitee opinion on state of the art and priorities for research. This data will be collected and presented in the first plenary talk, as well as an overview of the state of the art. These results can also serve as the default response when there is high degree of consensus, such that small group focus can be limited to areas where more discussion is needed to refine the status.

Wednesday, September 23, 2020

- Welcome, meeting overview and introduction [AWEurope, IEA Wind Task 11]
- Current state the AWE sector: short presentation for newcomers
- Non-technical discussion session with contributions from around the globe (short presentation and then Q&A, discussion)
    i. Resource Potential: Wind Study and Power Curves
    ii. AWE-specific support policies
    iii. Environmental and social impacts

- Technical discussion session with contributions from around the globe (short presentation and then Q&A, discussion)
    i. Safety aspects
    ii. Airspace Regulation
    iii. Need for common design tools
    iv. Experimental facilities
    v. Educational needs
- Synthesis

Thursday, September 24, 2020

- Welcome and separation into break-out sessions: panel discussion on selected key topics
    i. Two parallel breakout sessions so that people can provide feedback and change groups for the second round. Topics to be defined after the pre-meeting survey presentation on the first day.
- Plenary summary
    i. Discussion and consensus among participants
    ii. Defining potential points of collaboration with other IEA Wind tasks
    iii. Set up of an Advisory Board
- Timeline and next steps

A. ANNEX:

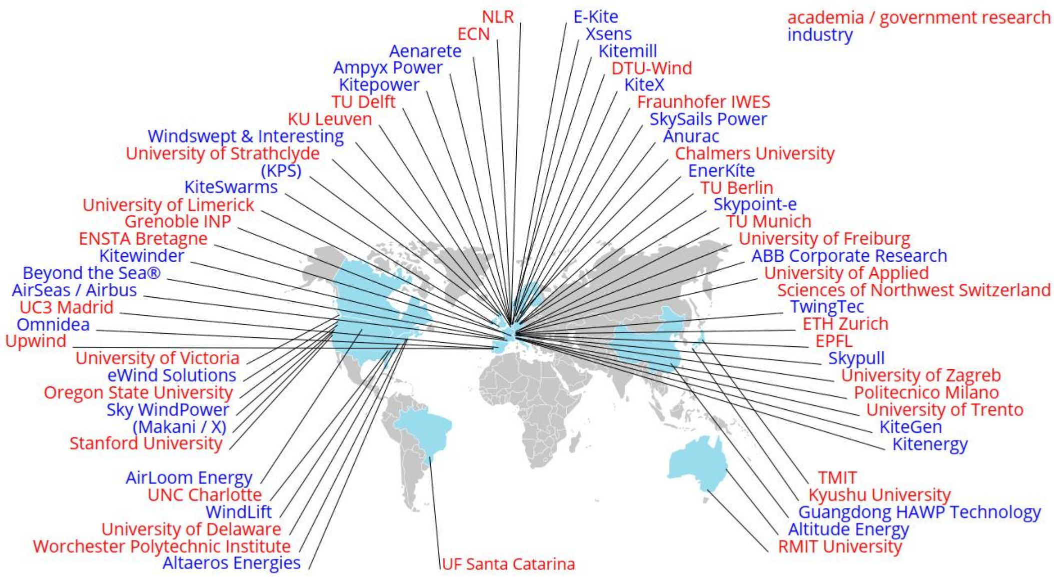


Figure 1: Organisations working on AWES. Source: R. Schmehl, TU Delft 2020

APPENDIX TWO – Meeting agenda

IEA Wind TEM#102 on Airborne Wind Energy

Online meeting, 23-24 September 2020

Meeting Agenda

Agenda 23-24 September 2020

Time	Topic	Presenter
Wednesday, 23 September 2020		
Introduction Session		
13:30 CEST	Check-in	All
13:30	Welcome and meeting overview	John McCann
13:35	IEA Wind TCP and Task 11	Nicolas El Hayek, *IEA Wind*
13:40	Speed-Dating - online meeting ice-breaker *3 min. break-out groups with 3 randomly chosen participants*	
13:45	Current state the AWE sector: Short presentation for newcomers	Udo Zillmann, *Airborne Wind Europe*
14:00	Vision(s) for Airborne Wind Energy Sector *Introductory note followed by 20 min. moderated plenary, collecting "visions" from different stakeholders, involvement in the industry.*	Roland Schmehl, *TU Delft*
14:20	"TEM mission statement" and criteria for selection of topics, level of risk and reward	Jochem Weber, *NREL*
14:30	Break (5 min.)	
Session 1		
14:35	*2 x 10 min. presentation per topic*	
14:40	1. Resource Potential: Wind Studies and Power Curves *Presentation plus Q&A*	Philip Bechtle, *Uni Bonn*
15:00	2. Environmental and social integration *Presentation plus Q&A*	Kristian Petrick, *AWEurope*
15:20	Moderated Break-out sessions on the two presented topics *Goals:* • *Provide feedback on topics* • *Identify/prioritise 3-5 specific topics which can form future Working Groups within an AWE Task* • *Identify potential points of collaboration with other IEA Wind tasks (e.g. Task 25 System integration, Task 26 Cost of Wind, Task 28 Social, Acceptance, Task 41 Distributed Wind, etc).* • *Potentially define Working Group Leaders*	
15:50	Plenary with short overview of results of break-out groups *Short discussion / Q&A (15 min.)*	
16.05	Break (25 min.)	
Sessions 2		

Time	Topic	Presenter
16:30	3. Safety aspects and airspace regulation *Presentation plus Q&A*	Michiel Kruijff, *Ampyx Power*
16:50	4. Common design tools, simulations and reference model *Presentation plus Q&A*	Chris Vermillion, *NC State University*
17:10	Moderated Break-out sessions on the two presented topics	
17:40	Plenary with short overview of results of break-out groups *Short discussion / Q&A (15 min.)* Short summary of the day	
18:00	Close of day	Brian Smith

Thursday, 24 September 2020		
13:30 AM	Check-in	All
5 min.	Welcome and Recap of Day 1	Kristian Petrick
3 min.	Speed-Dating *3 min. break-outs with 3 people randomly chosen by the system*	
Session 3		
13:40	5. Definitions, (performance) metrics, technology assessment *Presentation plus Q&A*	Jochem Weber, *NREL*
14:00	6. Electrical system *Presentation plus Q&A*	Christoph Hackl, *University of Applied Sciences Munich*
14:20	Moderated Break-out sessions on the two presented topics	
14:50	Plenary with short overview of results of break-out groups *Short discussion / Q&A (15 min.)*	Overall moderator: Kristian
15:10	Break (10 min.)	
Session 4		
15:20	7. Educational needs *Presentation plus Q&A*	Roland Schmehl, *TU Delft*
15:40	(3min intervention: AWE customer view) 8. Road mapping *Presentation plus Q&A*	Daniel Zywietz (Enerwhere) Jon Gjerde, *Airborne Wind Europe/Kitemill*
16:00	Moderated Break-out sessions on the two presented topics	
16:30	Plenary with short overview of results of break-out groups *Short discussion / Q&A (15 min.)*	
16:45	Break (15 min.)	
Final Session		
17:00	Discussion and consensus among all participants • Interactive poll • Noting potential participants for each thematic area	
17:20	Timelines and Next steps	Udo Zillmann
17:30	Event close	Nicolas El Hayek, *IEA Wind*

APPENDIX THREE – Survey Results

Overview vote at prior to the TEM

A poll conducted prior to the TEM gave the following prioritization of sub-topics:

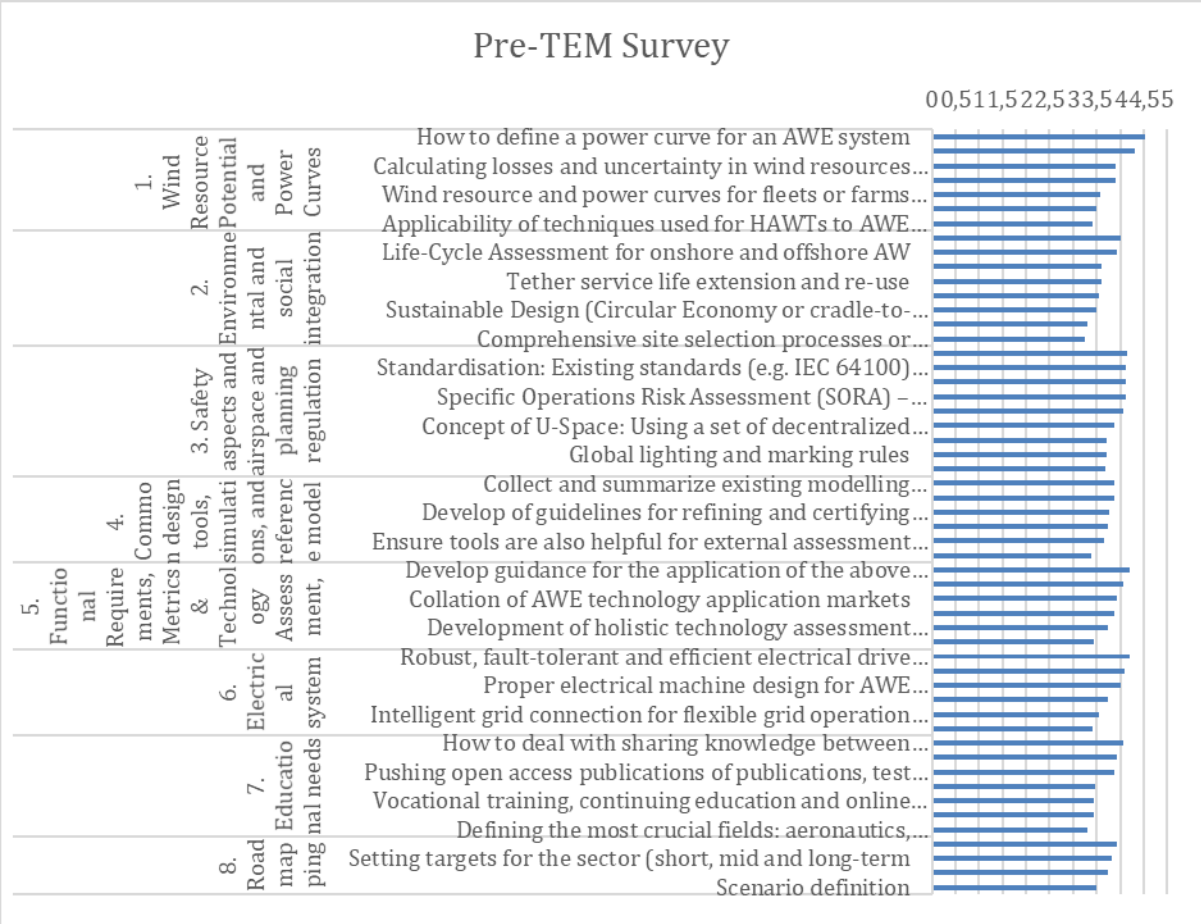


Figure 2: Pre-TEM Survey Results

Overview vote at the end of the TEM

A poll conducted at the end of the TEM gave the following prioritization of topics:

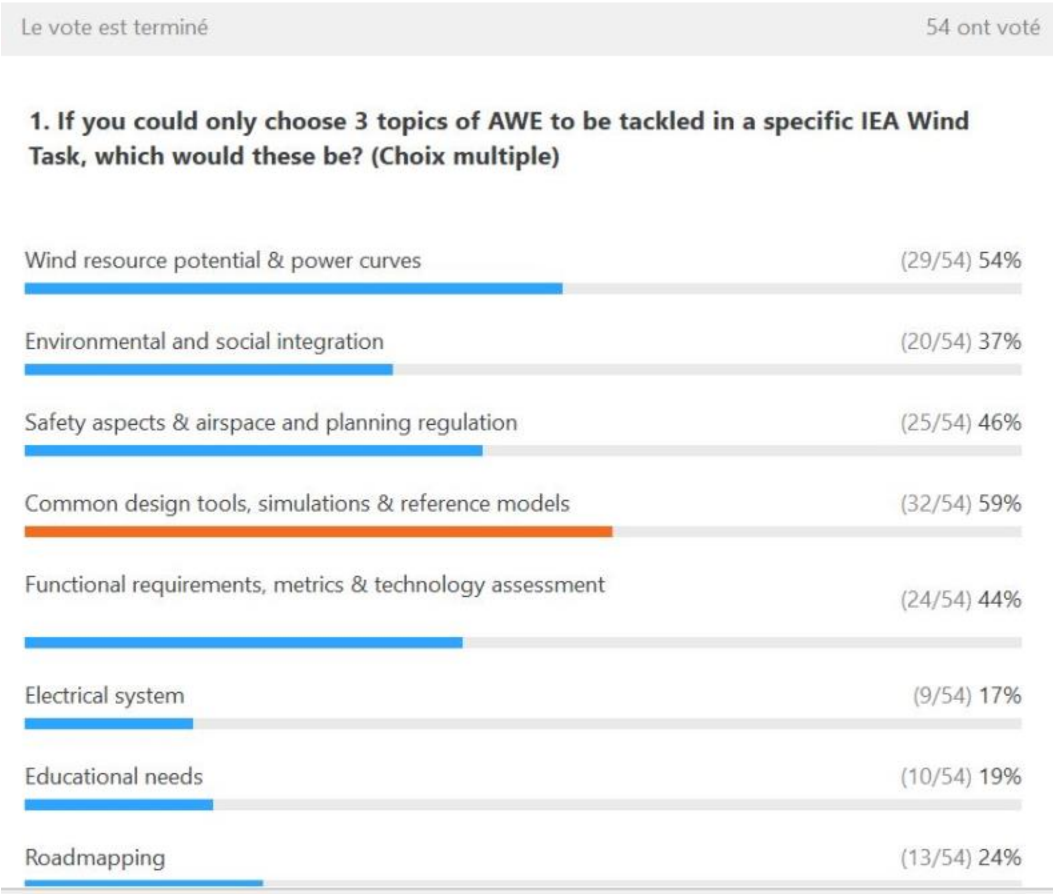


Figure 3: Post-TEM Survey results

Short description of key topics presented and discussed

1. Wind Resource Potential and Power Curves

A key advantage of AWE systems is that they can access wind at altitudes that are beyond the reach of conventional tower-based wind turbines and that the harvesting altitude can be adjusted continuously to the available wind resource. As a result, it is expected that AWE systems can reach higher capacity factors than conventional wind turbines. Because the operational envelope of AWE systems, especially those operated in pumping cycles, is more complex, the definition of power curves requires more care. Maximum extraction of wind power per land area could also vary from HAWT, due to differences in wake effects, variable altitudes and wind park density. Potential topics include:

1. The role of regional or national “wind atlases” and other resource summaries
2. Calculating losses and uncertainty in wind resources and energy production
3. How to define wind resources in a way that allows comparison of different systems
4. How to establish available wind resources at sites (e.g., remote sensing and simulation)
5. How to define a power curve for an AWE system
6. Wind resource and power curves for fleets or farms of AWE systems
7. Applicability of techniques used for HAWTs to AWE systems

2. Environmental and social integration

The environmental footprint and social impacts of AWE (e.g. bird collisions, noise, visual impacts) are largely unknown because there are only a few systems operational. The same holds true when it comes to benefits when comparing with other forms of energy generation, for instance reduced life-cycle-emissions, possibility to restore original site conditions, flexibility in operations. AWE can build on the experiences of onshore and offshore wind, avoiding to the extent possible negative impacts and perceptions, and to ensure that AWE is deployed in the most sustainable way possible. Potential topics include:

1. Bird collision risk modelling, validation and mitigation measures
2. Noise simulation, measurement and reduction measures
3. Investigation of how AWE are perceived by local population (visual impact, safety aspects, etc.)
4. Life-Cycle Assessment for onshore and offshore AWE
5. Sustainable Design (Circular Economy or cradle-to-cradle approach for choice of materials)
6. Tether service life extension and re-use
7. Guidance for sustainable deployment of AWE
8. Comprehensive site selection processes or involvement of local stakeholders

3. Safety aspects and airspace and planning regulation

In contrast to towered wind turbines, AWE systems include one or more flying components and as consequence reliability and safety are of crucial importance. While AWE systems based on softwings and rigid wings have different safety characteristics, they all require new standards and regulation. Potential topics include:

1. Standardisation: Existing standards (e.g. IEC 64100) and potential need for new ones
2. Specific Operations Risk Assessment (SORA) – Guidelines for AWE including Ground and Air Risk Mitigation
3. Developing common AWE regulation world-wide with related stakeholders (EASA, NAA, JARUS, EUROCAE, etc.)
4. Concept of U-Space: Using a set of decentralized services created to integrate drones (and AWE?) in the airspace and to enable them to operate together with manned aircraft.
5. Air safety requirements and Certification: Design organisation – DOA, Production organisation – POA, Continuing Airworthiness – CAO – relevance for the AWE
6. Future AWE categories: open, specific, certified
7. Definition of safety and operation zones
8. Planning /zoning regulation for AWE compared to HAWT wind parks
9. Global lighting and marking rules

4. Common design tools, simulations, and reference model

Several academic institutions have developed accurate, experimentally validated tools for the design, aerodynamic analysis, and simulation of airborne wind energy systems. In order to enable researchers within the community to build upon these results without rebuilding these models from first principles, there is a need for the dissemination and training on open-source AWES modelling tools (many of which exist but are not sufficiently widely known). Additionally, owing to the fact that several sets of modelling tools with essentially the same equations but different conventions are in existence, the creation of a working group for design and simulation tools is highly desirable. These tools are also important for third party assessment of AWE. Potential topics include:

1. Collect and summarize existing modelling frameworks (in terms of level of fidelity, restrictiveness (Fly-gen, ground-gen, or all? Which system components are included? Level of fidelity of the aerodynamic model, etc.)
2. Identify existing reference designs and how they should be categorized (e.g., MW-scale, 100kW-scale, etc.; Fly-gen and ground-gen? Rigid wings and kites?)
3. Identify dissemination, training, and versioning of modelling and simulation tools.
4. Develop of guidelines for refining and certifying modelling tools based on experimental data.
5. Discuss possible development of an inter-institutional modelling/reference model development working group.
6. Ensure tools are also helpful for external assessment of AWE.

5. Functional Requirements, Metrics & Technology Assessment,

Clear, holistic and solution-agnostic formulation of the problem statement along with effective technology assessment methods are critical in any research and technology development to be successful and success to achieved in the most cost, time and risk way possible. This is particularly the case for resource intensive technology development challenges and where a multitude of solutions concepts and technological implementations are possible. This research task will develop functional requirements, identify relevant metrics and develop technology assessment methods and tools for the AWE sector. It may utilize the learnings from related developments and the technology performance levels (TPL) in the wave energy sector. Potential topics include:

1. Collation of AWE technology application markets
2. Identification of functional requirements based on stakeholder requirements from all lifecycle stages – general and specific for the AWE markets
3. Identification of relevant metrics, quantitative and qualitative cost and performance drivers and characteristics
4. Development of holistic technology assessment methods and tools, including in the form of guides expert judgement
5. Develop guidance for the application of the above tools to identify the most cost, time and risk effective AWE technology development trajectories
6. Discuss relationship with group 4 (common design tools).

6. Electrical system

AWE technology poses a number of challenges to the electrical system, e.g. e.g. due to the extreme operation characteristics of pumping-mode AWE systems with their slow reeling-out and (very) fast reeling-in which leads to an extremely wide speed range of the electrical drive system. Moreover, the pumping cycle leads to an oscillating power generation which needs to be smoothed to accommodate grid operator needs. Solutions are intelligent power flow algorithms and parallelized operation of several AWE systems or flexible storage utilization. For on-board generation, the voltages must be stepped up to reduce losses in the power cables connected to the ground station. Finally, as voltage and frequency stability will become more and more important or even a DC grid connection will be required, a super flexible grid connection / integration must be designed for the next-generation power grid. These challenges must be solved in order to unfold the potential of the AWE technology compared to conventional wind turbine system. Potential topics include:

1. Robust, fault-tolerant and efficient electrical drive trains
2. Proper electrical machine design for AWE applications (e.g. reluctance synchronous machines, electrically-excited synchronous machines, multi-phase machines)
3. Modular, fault-tolerant and parallelizable power electronics system design and control (e.g. multi-level converters, dc/dc-converters)
4. Intelligent grid connection for flexible grid operation (grid-forming, -supporting, -feeding and black-start capability and DC connection)
5. Battery storage system design and intelligent integration in the optimal power flow (for single AWE systems or for entire farms)
6. Discussion of why/whether electrical systems require special focus in the IEA working group compared to other technical topics such as tethers, mechanical parts of ground station, wing, software, etc.

7. Educational needs

AWE is a relatively new and widely unknown field. Experienced people are scarce not only within the sector but also among important stakeholders like policy makers, utilities, administration, project developers, energy companies, etc. Professional networks like the European Academy of Wind Energy (EAWE) or conferences like the AWEC series facilitate knowledge exchange but more may be needed. Potential topics include:

- Design and offering of bachelor, master courses or networked PhD programmes (like the past EU H2020 doctoral programme AWESCO or the new national (Netherlands) NEON with 4 PhD students)
- Vocational training, continuing education and online courses – how to provide that, for whom and by whom? Examples are ProfEd courses or MOOCs.
- How to deal with sharing knowledge between competing companies?
- Defining the most crucial fields: aeronautics, programming, simulation, production techniques, electronics, mechanics, …
- Publishing books on AWE
- Pushing open access publications of publications, test datasets, reference data, ...
- Extending the number of conferences, events, webinars, meetings, etc.

8. Roadmapping

An AWE roadmap or research strategy needs to provide guidance and help validating the claims brought forward by the sector. In a study for the European Commission an AWE roadmap was suggested (see Ecorys 2018), and OEMs have started working on scenarios and milestones. However, a wider stakeholder group joined in a new AWE Task would bring in additional, valuable ideas to set targets, address barriers and challenges, and to prioritise activities. Potential topics include:

1. Setting targets for the sector (short, mid and long-term)
2. Scenario definition
3. Definition of milestones
4. Policy and regulatory aspects: key barriers and challenges

APPENDIX FOUR - Meeting Participants

A total of 92 participants were registered to TEM#102, coming from 18 countries across the globe. The online format of the meeting allowed again for a broader participation than usual for TEMs, with the number of participants each day exceeding 80. TEM#102 saw an especially active participation in the breakout sessions.

The detailed list of participants for the meeting is available on the TEM#102 website. A log-in is necessary to view the files.

A deck of introductory slides to 51 of the participants was put together, highlighting their background and research interest. This document is available for download at this link.

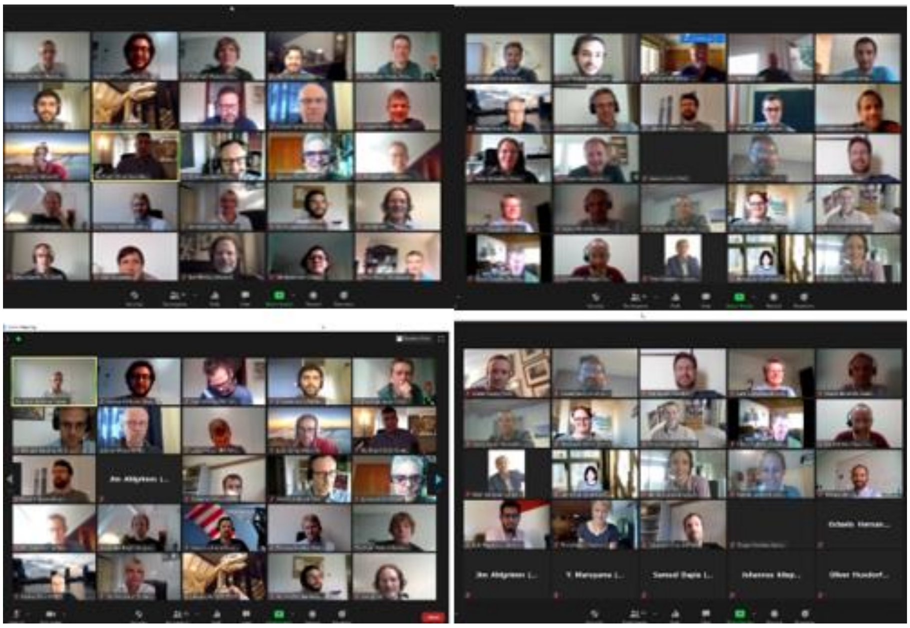


Figure 4: Group picture on Zoom

More than half of the participants came from three countries: Germany, USA and The Netherlands.

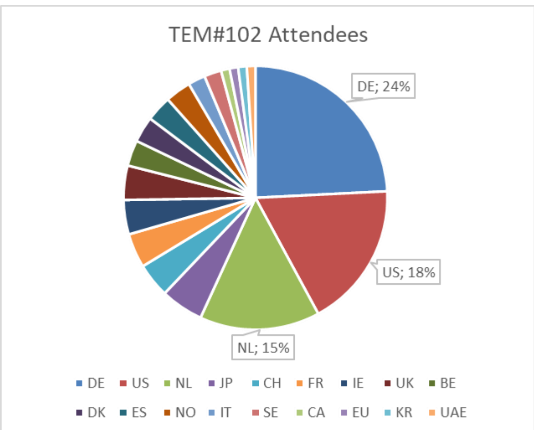


Figure 5: Country distribution of participants

APPENDIX FIVE - IEA Agreement

International Energy Agency Agreement

Implement Agreement for Co-operation in the Research, Development and Deployment of Wind Turbine Systems (IEA Wind)

The IEA international collaboration on energy technology and RD&D is organized under the legal structure of Implementing Agreements, in which Governments, or their delegated agents, participate as Contracting Parties and undertake Tasks identified in specific Annexes.

The IEA's Wind Implementing Agreement began in 1977 and is now called the Implementing Agreement for Co-operation in the Research, Development, and Deployment of Wind Energy Systems (IEA Wind). At present, 26 contracting parties from 22 countries, the European Commission, and Wind Europe, participate in IEA Wind. Austria, Belgium, Canada, CWEA, Denmark, the European Commission, Finland, France, Germany, Greece, Ireland, Italy (two contracting parties), Japan, Republic of Korea, Mexico, Netherlands, Norway (two contracting parties), Portugal, Spain, Sweden, Switzerland, United Kingdom, the United States and WindEurope are now members.

The development and maturing of wind energy technology over the past 30 years has been facilitated through vigorous national programs of research, development, demonstration, and financial incentives. In this process, IEA Wind has played a role by providing a flexible framework for cost-effective joint research projects and information exchange.

The mission of the IEA Wind Agreement continues to be to encourage and support the technological development and global deployment of wind energy technology. To do this, the contracting parties exchange information on their continuing and planned activities and participate in IEA Wind Tasks regarding cooperative research, development, and demonstration of wind systems.

Task 11 of the IEA Wind Agreement, Base Technology Information Exchange, has the objective to promote and disseminate knowledge through cooperative activities and information exchange on R&D topics of common interest to the Task members. These cooperative activities have been part of the Wind Implementing Agreement since 1978.

Task 11 is an important instrument of IEA Wind. It can react flexibly on new technical and scientific developments and information needs. It brings the latest knowledge to wind energy players in the member countries and collects information and recommendations for the work of the IEA Wind Agreement. Task 11 is also an important catalyst for starting new tasks within IEA Wind.

IEA Wind TASK 11: BASE TECHNOLOGY INFORMATION EXCHANGE

The objective of this Task is to promote disseminating knowledge through cooperative activities and information exchange on R&D topics of common interest. Four meetings on different topics are arranged every year, gathering active researchers and experts. These cooperative activities have been part of the Agreement since 1978.

Three Subtasks

The task includes three subtasks.

The objective of the first subtask is to develop recommended practices (RP) in collaboration with the other IEA Tasks.

The objective of the second subtask is to conduct Topical Expert Meetings (TEM) in research areas identified by the IEA R&D Wind Executive Committee. The Executive Committee designates topics in research areas of current interest, which requires an exchange of information. So far, TEMs are arranged four times a year. Additional TEM types that would allow shorter reaction times, broader audience and augmented visibility are currently being researched.

The objective of the third subtask is to provide room for exchanges within the wind energy expert community. This is done through the IEA Wind platform with online communities.

Documentation

Since these activities were initiated in 1978, more than 90 volumes of proceedings have been published. In the series of Recommended Practices, 20 documents were published and six of these have revised editions.

All documents produced under Task 11 and published by the Operating Agent are available to citizens of member countries participating in this Task. Some documents are publicly available one year after first publication.

Operating Agent

Planair SA
Rue Galilée 6
1400 Yverdon-les-Bains
Switzerland
Phone: +41 24 566 73 02
E-mail: ieawindtask11@planair.ch

COUNTRIES PRESENTLY PARTICIPATING IN TASK 11 (2020)	
COUNTRY	**INSTITUTION**
Belgium	Government of Belgium
Canada	Natural Resources Canada
Denmark	Danish Energy Authority
Finland	Business Finland
Germany	Federal Ministry for Economic Affairs and Energy (BMWi)
Ireland	Sustainable Energy Authority of Ireland (SEI)
Italy	Ricerca sul sistema energetico (RSE S.p.A.)
Japan	New Energy and Industrial Technology Development Organization (NEDO)
Mexico	Instituto de Investigaciones Electricas (IIE)
Netherlands	Ministry of Economic Affairs
Norway	The Norwegian Water Resources and Energy Directorate (NVE)
Republic of China	Chinese Wind Energy Association (CWEA)
Republic of Korea	Korea Institute of Energy Technology Evaluation and Planning (KETEP)
Spain	Centro de Investigaciones Energeticas, Medioambientales y Tecnologicas (CIEMAT)
Sweden	Energimyndigheten - Swedish Energy Agency
Switzerland	Swiss Federal Office of Energy (SFOE)
United Kingdom	Offshore Renewable Energy CATAPULT
United States	The U.S Department of Energy (DOE)